Acoustic Scattering from Heterogeneous Rough Seabeds

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LONG-TERM GOALS

The goals of this research is to better understand the physics and mechanisms of sound-seabed interaction, including acoustic penetration, propagation, attenuation and scattering in marine sediments.

OBJECTIVES

Scientific objectives of this research is to assess the importance of different mechanisms of seabed scattering and their interactions, and to provide their physically understandable description at mid- and high-frequencies. Also, the research will contribute to modeling and inversions for the ASIAEX program for studying shallow water reverberation, and emphasizes the physics of bottom reverberation. Specifically, this research will provide methods for direct testing of hypotheses for the dominant mechanisms of seabed scattering.

APPROACH

There are different scattering mechanisms, which are generally can be attributed to two different types of seabed medium irregularities: volume heterogeneity such as continuous fluctuations of the sediment acoustic parameters and discrete inclusions (rock, shell hash, etc), and roughness of the water-sediment interface. The two mechanisms of seabed scattering, surface roughness and volume heterogeneity, can operate at the same time, and thus methods for their separate identification are of practical importance.

In this research, a correlation method has been developed, which permits separation and identification of volume and surface components of the scattered field. The method involves measurements of spatial

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15. SUBJECT TERMS

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coherence of the field with a linear array located near the source. Additionally, it allows measurement of the volume scattering strength and sound attenuation in sediment, quantities that are normally not separable in reverberation data. Thus, it provides, in particular, a new means of measuring the frequency dependence of attenuation for testing current models, some of which predict linear dependence while others predict more complicated dependence on frequency.

WORK COMPLETED

Measurements of the spatial coherence of the scattered field can be used to separate contributions of volume and roughness components or, if there is only one component, to determine its type. It is was shown [3] that the partial roughness and volume components of the total field may have significantly different coherence scales, L_r and L_v, e.g., $L_r >> L_v$. Then the intensities of these components can be determined separately using measurements of the spatial coherence of the total field at different values of separation between receivers, L. In particular, at $L_r >> L >> L_v$, a spatial "filtration" occurs, which leaves only the roughness component of the scattered field and eliminates the volume component.

As an example, consider the vertical coherence of a spherical narrow band impulse of duration τ and period T, scattered nearly backward from the rough heterogeneous sediment volume. The expressions for the partial roughness and volume coherence coefficients were obtained in [3]. The roughness scatter spatial correlation scale, L_r, appears to be independent of sediment parameters and is controlled by the duration of the incident signal. The volume scatter spatial correlation scale, L_v, is independent of signal duration and controlled by sediment parameters (sound attenuation). The condition $L_r >> L_v$ results in the requirement of a short enough, but still narrow-band, impulse such that $\pi\delta << T/\tau << 1$, where δ is the loss parameter of the sediment, which is frequency independent only if the attenuation coefficient, β, is proportional to frequency.

It is easy to see from the considerations above that measuring the coherence at different pulse duration can be used to determine the type of scattering, volume or roughness. If both types operate at the same time, the intensities of these components, and consequently the seabed roughness and volume scattering strengths, can be determined separately. Measuring the coherence scale of volume component additionally permits the determination of the loss parameter, δ, and correspondingly, the attenuation coefficient, β. Then, using existing models of volume scattering, the scattering cross section per unit volume and the spectrum of heterogeneity can be determined.

As an example, in Figure 1, the spatial coherence for near backscattering directions is shown at $H = 30$ m, $\chi = 60°$, $\delta = 0.005$ (silt), where H is the distance between the receiving array and the seabed surface, and χ is the grazing angle. Different relative contributions of volume and roughness components are considered: only volume (V), only roughness (R), and their equal contributions (V+R).

The ratio of the intensity of the roughness component to the intensity of the total scattered field, 0.5, seems to be easy to invert from the evident two scale behaviour of the coherence with the shorter pulse.

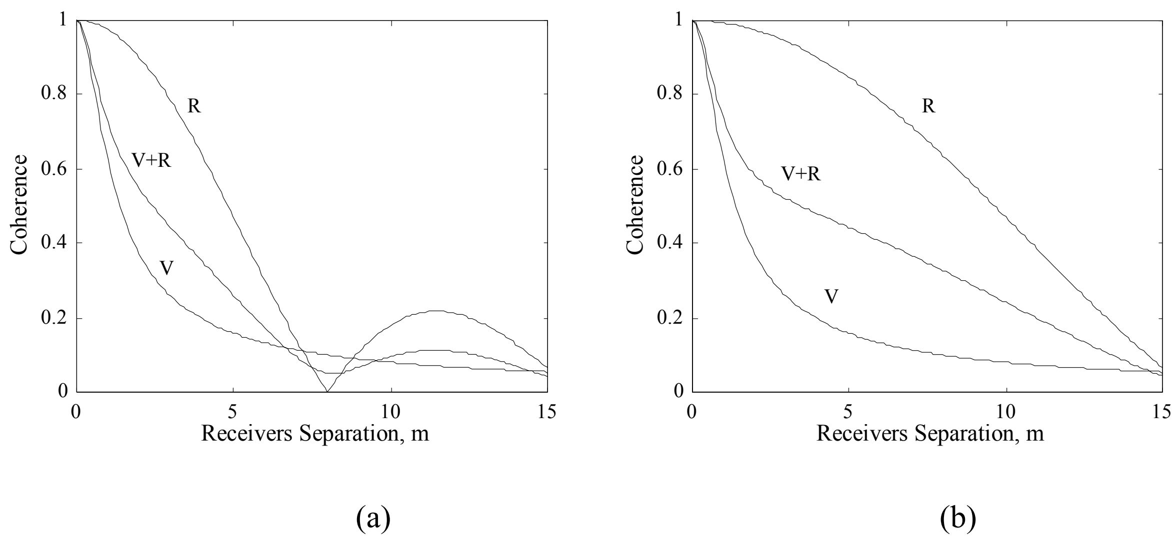

Figure 1. Magnitude of the coherence coefficient for two different pulse duration, $\tau = 10T$ ***(a) and*** $\tau = 5T$ ***(b). Two scale behaviour of the coherence is evident for the shorter pulse.***

Note that spatial correlation scales of the scattered field in the far field zone are determined by the angular size of the scattering volume or surface "visible" from the viewpoint of the receiver. For roughness scattering, this angular size is defined by the insonified footprint at the seabed surface, which is proportional to the duration of the incident impulse. For volume scattering, the angular size is defined by the penetration depth, which is independent of the pulse duration. Thus, at sufficiently short pulses, the angular size for the scattering surface becomes much smaller than for the scattering volume. Correspondingly, this causes the difference in spatial correlation scales for roughness and volume components. The same considerations are valid for a horizontal array and for other types of scatterers, e.g., discrete ones on the surface and in the volume of sediments.

RESULTS

It is shown that the correlation scales for the volume and surface components can be significantly different, and thus spatial filtration can be used for separating these components. This method would also permit separate measurement of the scattering strength per unit area of bottom surface, the scattering strength per unit volume and sound attenuation in the sediment.

IMPACT/APPLICATIONS

The models of seabed scattering developed in this research will provide a better understanding of bottom acoustic interaction at mid- and high-frequencies and can be used as a basis for improved algorithms for remote acoustic inversions for seafloor properties.

TRANSITIONS

The results of this work are being adapted in practical models for seabed scattering. For example, a high-frequency bistatic scattering model funded by the ONR Torpedo Environments Program (6.2) incorporates the seabed scattering model developed as part of this work. The correlation method for identification and/or separation of the volume and roughness components of scattering was proposed for using during ASIAEX and other ONR experiments.

RELATED PROJECTS

This research is conducted jointly with the separately funded work of D.R. Jackson and T.K. Stanton. The approaches and models developed in this research are relevant to acoustic penetration and volume scattering issues arising within the ONR Departmental Research Initiative on high-frequency sound interaction with the seafloor.

PUBLICATIONS

1. K. Briggs, K. Williams, D. Jackson, C. Jones, A. Ivakin and T. Orsi (2002), "Influence of fine-scale sedimentary structure on high-frequency acoustic scattering", Marine Geology, **182**, 141-159.

2. Ivakin A.N. (2001), "Acoustic scattering from stratified marine sediments ", J. Acoust. Soc. Amer., **110**(5), Pt.2, p.2661-2662 (A).

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